

STUDY OF EDM PROCESS PARAMETERS OF SURFACE ROUGHNESS IN TITANIUM USING TAGUCHI METHOD

M. MATHESWARAN¹ & P. SURESH²

¹M. Tech Student, Paavai Group of Institutions, Namakkal, Tamil Nadu, India

²Professor, Department of Mechanical Engineering, Karpagam College of Engineering, Coimbatore, Tamil Nadu, India

ABSTRACT

In this paper, an orthogonal array, the signal-to-noise (S/N) ratio, and analysis of variance ANOVA) are used to study the performance characteristics in machining operations of titanium material using copper electrode as machining tool. In machining, the process parameters (current, pulse on time, and pulse off time) are studied in favour of getting optimum surface roughness property. Through this study, not only can the optimal machining parameters for machining process be obtained, but also the main machining parameters that affect the machining performance in EDM process can be found. Experimental results have shown that the effectiveness of this approach.

KEYWORDS: Electric Discharge Machining (EDM), Taguchi Method, Optimization, Surface Roughness

INTRODUCTION

In a EDM process, it is an important task to select machining parameters for achieving high machining performance. Usually, the desired machining parameters are determined based on experience or by use of a handbook. However, this does not ensure that the selected machining parameters have optimal or near optimal machining performance for a particular machine and environment. Machining parameters are reflected on surface roughness, surface texture and dimensional deviations of the product. Surface roughness, which is used to determine and to evaluate the quality of a product, is one of the major quality attributes of a EDM product.

Surface roughness is a measure of the technological quality of a product and a factor that greatly influences manufacturing cost. It describes the geometry of the machined surfaces and combined with the surface texture. The mechanism behind the formation of surface roughness is very complicated and process dependent. To select the machining parameters properly, several mathematical models [1–2] based on statistical regression or neural network techniques have been constructed to establish the relationship between the machining performance and machining parameters. Then, an objective function with constraints is formulated to solve the optimal machining parameters using optimization techniques. Therefore, considerable knowledge and experience are required for this approach. In this study, an alternative approach based on the Taguchi method [3–4] is used to determine the desired machining parameters more effectively.

Basically, the Taguchi method is a powerful tool for the design of high quality systems. It provides a simple, efficient and systematic approach to optimize designs for performance, quality, and cost. The methodology is valuable when the design parameters are qualitative and discrete.

TAGUCHI METHOD

Optimization of process parameters is the key step in the Taguchi method for achieving high quality without increasing cost. Basically, classical process parameter design [5] is complex and not easy to use. A large number of experiments have to be carried out when the number of process parameters increases.

To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire process parameter space with a small number of experiments only. Taguchi recommends the use of the loss function to measure the performance characteristic deviating from the desired value. The value of the loss function is further transformed into a signal-to-noise (S/N) ratio. Usually, there are three categories of the performance characteristic in the analysis of the S/N ratio, that is, the lower-the-better, higher-the-better, and nominal-the-better. The S/N ratio for each level of process parameters is computed based on the S/N analysis. Regardless of the category of the performance characteristic, the larger S/N ratio corresponds to the better performance characteristic. Therefore, optimal level of the process parameters is the level with the highest S/N ratio.

Furthermore, a statistical analysis of variance (ANOVA) is performed to see which process parameters are statistically significant [6]. With the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. In this paper, the machining parameter design by the Taguchi method is adopted to obtain optimal machining parameter for surface roughness in EDM.

EDM PROCESS EXPERIMENTS

Electrical Discharge Machining (EDM) is one of the most widely applied non-conventional machining processes in which a electrode act as a machining tool removes material from the surface of a work piece by means using thermal energy to generate heat that melts and vaporizes the work piece by ionization within the dielectric medium. A common method of evaluating machining performance in a EDM process is based on the surface roughness. Basically, surface roughness is strongly correlated with machining parameters such as Peak Current, Pulse on Time, and Pulse off Time. Proper selection of the machining parameters can obtain better surface roughness. Hence, optimization of the machining parameters based on the parameter design of the Taguchi method is adopted in this paper to improve surface roughness in an EDM process.

Selection of Machining Parameters and their Levels

The machining experiments were carried out on a Sparknionix-Electric Discharge Machine using Copper Electrode as tool machining of titanium material. The three levels of the machining parameters selected were shown in Table 1.

Table 1: Machining Parameters and their Levels

Symbol	Parameter	Unit	Level 1	Level 2	Level 3
A	Peak Current	Amps	6	10	14
B	Pulse on time	μ s	120	450	650
C	Pulse on time	μ s	20	40	75

Machining Performance Measure

The work piece surface roughness (Ra) measurements were made over EDM machined surfaces using a Mitutoyo Surftest 211. The cut-off length (λ_c) of 2.5 cm and the number of sampling (L) of five were used in the measurements. The surface roughness measurements given in this study are the mathematical average of three readings taken from the work piece.

DETERMINATION OF OPTIMAL MACHINING PARAMETERS

In this section, the use of an orthogonal array to reduce the number of machining experiments for determining the optimal machining parameters is reported. Results of the machining experiments are studied by using the S/N and ANOVA analyses. Based on the results of the S/N and ANOVA analyses, optimal machining parameters for surface roughness are obtained and verified.

Orthogonal Array Experiment

In this study, an L_9 orthogonal array with four columns and nine rows has been used. This array has eight degrees of freedom and it can handle three-level design parameters. Each machining parameter is assigned to a column, nine machining-parameter combinations being available. Therefore, only nine experiments are required to study the entire parameter space using the L_9 orthogonal array. The experimental layout for the three machining parameters using the L_9 orthogonal array is shown in Table 2. Since the L_9 orthogonal array has four columns, one column of the array is left empty for the error of experiments: orthogonality is not lost by letting one column of the array remain empty Table 3. Shows the experimental results and S/N ratio of surface roughness.

Table 2: Experimental Layout Using an L_9 Orthogonal Array

Ex. No.	Machining Parameter Level			
	A Peak Current (Amps)	B Pulse On Time(μ s)	C Pulse Off Time(μ s)	D Error
1	1	1	1	-
2	1	2	2	-
3	1	3	3	-
4	2	1	2	-
5	2	2	3	-
6	2	3	1	-
7	3	1	3	-
8	3	2	1	-
9	3	3	2	-

Analysis of the Signal-To-Noise (S/N) ratio

As mentioned earlier, there are three categories of performance characteristics, i.e., the lower-the-better, the higher-the-better, and the nominal-the-better. To obtain optimal machining performance, the lower-the-better performance characteristic for surface roughness has been taken for obtaining optimal machining performance. Table 4 shows the experimental results for surface roughness and the corresponding S/N ratio using the equation

$$S/N (\eta) = -10 \log \left(\frac{1}{n} \sum_{i=1}^n y_i^2 \right)$$

Since the experimental design is orthogonal, it is then possible to separate out the effect of each machining parameter at different levels. The mean S/N ratio for each level of the machining parameters is summarized in Table 5 and is called the mean effect response for surface roughness. In addition, the total mean S/N ratio for the nine experiments is also calculated and listed in Table 4.

Table 3: Experimental Results for Surface Roughness and S/N Ratio

Ex. No.	Machining Parameter Level			Surface Roughness Ra (μm)	S/N ratio (dB)
	A Peak Current (Amps)	B Pulse on Time(μs)	C Pulse Off Time(μs)		
1	6	100	20	4.19	-12.4443
2	6	450	40	5.49	-14.7914
3	6	650	75	6.28	-15.9592
4	10	100	40	4.36	-12.7897
5	10	450	75	5.69	-15.1022
6	10	650	20	6.68	-16.4955
7	14	100	75	4.15	-12.3610
8	14	450	20	5.45	-14.7279
9	14	650	40	6.25	-15.9176

Table 4: Mean Effect Response for Surface Roughness

Symbol	Machining Parameters	Mean Multi-Response S/N Ratio (Db)			
		Level -1	Level - 2	Level - 3	Max. – Min.
A	Peak Current	-14.3983	-14.7958	-14.3355	0.4604
B	Pulse on Time	-12.5317	-14.8739	-16.1241	3.5925
C	Pulse off Time	-14.5559	-14.4996	-14.4741	0.0818

Total mean S/N ratio = -14.5099 dB

Analysis of Variance

The experimental results were analyzed with analysis of variance (ANOVA), which is used for identifying the factors significantly affecting the performance measures. The result of the ANOVA is shown in Table 6. This analysis was carried out for a significance level of $\alpha = 0.05$, i.e. for a confidence level of 95%. From Table 5 it is apparent that the F ratio values of parameters A and B (Peak Current, Pulse on Time) are higher than F ratio values drawn from table ($F_{2,2}=19.0$). Factor C (Pulse off Time) is not a significant parameter affecting surface roughness, since its F ratio value = 0.0516 is less than $F_{2,2}=19.0$. Therefore, based on the S/N and ANOVA analyses, the optimal machining parameters for surface roughness are the Peak Current at level 3, the Pulse on Time at level 1, and the Pulse off Time at level 3.

Table 5: Computation of ANOVA

Symbol	Machining Parameter	Df	Sum of Squares	Variance	F-Value	F-Ratio from Table	C %
A	Peak Current	2	0.3738	0.1869	53.23	19	1.8376
B	Pulse on Time	2	19.955	9.9774	2840.81	19	98.076
C	Pulse off Time	2	0.0110	0.0053	1.4956	19	0.0516
Error		2	0.0070	0.0044			0.0345
Total		8	20.3462				100

Confirmation Tests

Once the optimal level of the design parameters has been determined, the final step is to predict and verify the quality characteristic using this optimal level of design parameters. The estimated S/N ratio η_{opt} using the optimal level of the design parameters can be calculated as

$$\eta_{opt} = \bar{\eta} + \sum_{j=1}^o (\eta_j - \bar{\eta})$$

where ' $\bar{\eta}$ ', the total mean of the S/N ratio, η_j is the mean S/N ratio at the optimal level and 'o' is the number of process parameters that significantly affect the performance characteristics. Table 6 shows the results of the confirmation experiment using the optimal machining parameters of surface roughness.

Table 6: Results of the Confirmation Experiment for Surface Roughness

Initial Machining Parameters		Optimal Machining Parameters	
		Prediction	Experiment
Level	A ₁ B ₁ C ₁	A ₃ B ₁ C ₃	A ₃ B ₁ C ₃
Surface roughness (μm)			
S/N ratio (dB)	-12.4443	-12.3573	-12.3610
Improvement of S/N ratio		0.0870	

CONCLUSIONS

This paper has presented an application of the parameter design of the Taguchi method in the optimization of EDM process. The following conclusions can be drawn based on the experimental results of this study:

- The experimental results demonstrate that the Peak Current and Pulse on Time are the main parameters among the three controllable factors (Peak Current, Pulse on Time and Pulse off Time) that influence the surface roughness in Titanium.
- Surface roughness can be improved simultaneously through this approach instead of using engineering judgment. The confirmation experiments were conducted to verify the optimal Machining parameters. The percentage contributions of Peak Current, Pulse on Time and Pulse off Time are 1.8376, 98.076 and 0.0516 respectively.
- The optimal level of EDM process parameter to obtain good surface finish of Titanium is A₃B₁C₃ (Peak Current 12Amps, Pulse on Time 100μs and Pulse off Time 75 μs)
- These levels of parameters would enable the EDM process with higher degree of surface finish.

REFERENCES

1. Ross PJ. *Taguchi techniques for quality engineering*. New York: McGraw-Hill; 1988.
2. Yang H, Tarng YS. *Design optimization of machining parameters for turning operations based on the Taguchi method*. *J Mater Process Technol* 1998; 84:122–9
3. Abuelnaga AM, El-Dardiry MA. *Optimization methods for metal machining*. *Int J MachTool Design Res* 1984; 24(1):11–8.

4. Chua MS, Rahman M, Wong YS, Loh HT. Determination of optimal machining Conditions using design of experiments and optimization techniques. *Int J MachTools Manuf* 1993; 33 (2): 297–305.
5. Yih-fong Tzeng, Fu-chen Chen. Multi-objective Optimization of high – speed electrical discharge machining process using a Taguchi fuzzy- based approach. *Material and Design* (2006).
6. D.C. Montgomery, *Design and Analysis of Experiments*, Wiley, Singapore, 1991.
7. Shaw MC. *Metal machining principle*. New York: Oxford University Press; 1984.